

Government were unwilling to appoint any commission for the Universities of Oxford or Cambridge until full opportunity had been given to these Universities to make necessary reform for themselves. In the five years that have since elapsed various proposals for constitutional reform have been brought before the Senate of the University of Cambridge by the council of the Senate, but they have been, without exception, rejected by the Senate; and it is clear to us that no further attempt of the kind is likely to be successful. We therefore make our present appeal for the appointment of a commission.

### *ELECTRICITY SUPPLY: PAST, PRESENT, AND FUTURE.<sup>1</sup>*

IT was in 1882 that Parliament passed the first of the Electric Lighting Acts. This Act was in part based upon recommendations made by a Select Committee on Lighting by Electricity that sat in 1879, and as an instance of the want of proportion in the ideas that then prevailed it may be mentioned that before that committee Mr. Joseph Rayner, the Town Clerk of Liverpool, explained that one of the reasons why the Corporation of Liverpool were seeking for Parliamentary powers to supply electricity within their borough was because they were in a specially advantageous position to do this, as they had an engine which was used during the daytime for working a fountain, and might well be used for supplying electricity during the night, that engine having a capacity of 20 horse-power. At the end of last year the electric supply plant of the Corporation of Liverpool amounted to about 50,000 horse-power, which, when compared with this 20 horse-power engine, affords a commentary on the parochial character of the ideas in accordance with which the first of the Electric Lighting Acts was framed.

In the year 1882, also, the first electric supply station for supplying incandescent lamps on a public scale in London was established by the Edison Company on Holborn Viaduct. The Holborn station was equipped with two Edison dynamo machines, and it is interesting, as giving an inkling of the notions then prevailing, that these machines were described by the then editor of one of our chief engineering papers as "enormous," it being added, evidently as a matter of wonder, that "no less than 1000 full size or 16-candle incandescent electric lamps were maintained constantly in operation from one machine." It may be mentioned that each of these dynamos was driven by a high-pressure Porter engine of 130 horse-power, which shows that even in 1882 ideas had not progressed very far beyond those to which I have already alluded in connection with Liverpool three years earlier. The design of these early Edison machines, with their multiple-magnet limbs each with its separate winding, is also illustrative of the ignorance then prevailing on electromagnetic subjects, it being obvious in the light of modern knowledge that the arrangement was altogether inefficient and absurd. It was the late Dr. John Hopkinson who first put the design of continuous-current dynamos and their magnetic circuits on a sure foundation.

So far from assisting electricity supply, the Electric Lighting Act of 1882 had the immediate effect of crushing enterprise in that direction, the period of seven years for which licences, or the twenty-one years for which provisional orders, were granted to promoters of electric supply undertakings being found quite inadequate to enable money to be

raised for such purposes. Between 1883 and 1888, when the Act was amended, only ten licences were applied for, all of which afterwards expired or were revoked, and though in the first year there were a considerable number of applications for provisional orders, not one of these was carried into effect, capitalists refusing to find money for undertakings which had only a tenure of twenty-one years. No doubt, also, this unsatisfactory result was assisted by the severe reaction that had set in from the speculative mania in electric lighting affairs of a few years earlier.

It was not until 1885 that Sir Coutts Lindsay laid down an installation in Bond Street to light the Grosvenor Picture Gallery and the premises of some of the neighbouring tradesmen, which installation in its subsequent development had probably more influence than anything else on the fortunes of electricity supply, not only in London, but in the country generally. Quite a novel system of distribution was employed, the current being alternating and distributed at high pressure by means of overhead wires, and transformers (or secondary generators, as they were called) on the Goulard and Gibbs system being used to reduce the pressure to suit that of the lamps.

To begin with, the system did not work well, and, on the advice of Lord Kelvin, Mr. S. Z. de Ferranti was called in to assist. The station was immediately reorganised and fitted with machinery of much greater capacity, and so successful was the outlook that, early in 1888, the London Electric Supply Corporation, Ltd., was formed with a capital of 1,000,000*l.* sterling, and what were then considered as immense works were started upon as far away as Deptford, six miles from the centre of London, the scheme being to transmit the electricity from where land, coal, labour, and water for condensing could be cheaply obtained, at a pressure of no less than 10,000 volts, with suitable substations where it could be transformed and thence distributed at lower pressures. The great courage shown by those responsible for the venture was deserving of a better fate—but alas for the uncertainty of human endeavours! While the working of the station at Deptford was still in its inception, the plant at the Grosvenor Gallery became ignited by a short circuit and was burnt out; while the London Electric Supply Corporation soon afterwards went into the hands of a receiver, leaving unfinished, and never to be finished, the 10,000 horse-power sets of dynamo and engine which Mr. Ferranti's genius had dared to devise.

Though so very unsuccessful financially at its first start off, there can be no question as to the enormous influence that the Deptford undertaking had on the history of electricity supply, not only in London or in this country, but throughout the world. Here, at length, was an electricity supply proposition on a scale similar to those of the great undertakings that furnish gas to the Metropolis, with generating plant and means of distribution designed for the sale of electricity over a large portion of London. The more cautious procedure adopted by other concerns which sprang up about the same time and later was no doubt more successful from a business point of view, but the impulse given by this ambitious scheme became manifest from the great competition that was shown for provisional orders for different parts of London, leading to the public inquiry that was held by the Board of Trade immediately after the passing of the amended Electric Lighting Act of 1888, in which the period of twenty-one years, after which the undertaking was subject to purchase without any allowance for goodwill, was extended to forty-two years.

<sup>1</sup> From a discourse delivered at the Royal Institution on Friday, April 19, by Alan A. Campbell Swinton.

It is worthy of note that the London Electric Supply Corporation has now some time ago successfully emerged from its period of financial distress, while Mr. Ferranti, though, as has been shown, he was one of the pioneers of electricity supply, still remains with us as one of the most vigorous intellects in the electrical industry, and one who, as president of the Institution of Electrical Engineers, is even now dreaming fresh dreams of higher things and lower costs so far as electricity supply is concerned.

During the period with which we have been dealing, so far as the public were then aware, the chief improvements that had been effected in connection with machinery for electricity supply had reference to the dynamos which generated the current, the batteries that stored it, the cables and switches and other apparatus that distributed it and regulated its performances. True, to some extent, special designs of steam engines had been got out to suit the requirements of driving the fast-running dynamos, as, for instance, the well-known Willan's engine. As yet, however, there had been no departure from the reciprocating engine.

Early in the year 1885 the present speaker had the privilege, for the first time, of seeing running in the works of Messrs. Clark, Chapman and Parsons, Gateshead-on-Tyne, the first true rotary engine that ever gave useful results. The invention had been patented by Sir Charles Parsons in April, 1884, and in the interval this first practical steam turbine had been constructed. I am able to show you the actual machine, which the South Kensington Museum authorities have kindly sent here, withdrawing it for the evening from the congenial company of Watt's beam engine and Stephenson's "Rocket," amongst which it now has its appropriate abode.

As will be seen, it is a very small machine directly coupled to a dynamo giving about six electrical horsepower when running at the great speed of 18,000 revolutions per minute, and it is interesting to compare its parts, as, for instance, its blading, with that of the very large steam turbines on exactly the same principle that have been constructed in recent years, as, for instance, portions of blading such as is used in the turbines of the *Mauretania*, which, through the courtesy of Messrs. C. A. Parsons and Co., I am also able to bring to your notice.

The steam turbine has now come into very general use, being employed to the almost complete exclusion of other heat engines where very large electrical powers are wanted. At its inception, however, its inventor had many difficulties to encounter, together with much prejudice. Since the days of James Watt inventors up to that time had been continually trying to produce a successful rotary engine, and all had failed. It was natural, therefore, for engineers to ask why this new inventor should succeed any more than those who had gone before. They did not realise that the advances that had been made in thermodynamics, and more especially in machine tools and workshop methods, had rendered things practicable which, up till that time, had not been so; nor did they understand that here at last the subject was being tackled on really scientific principles by one exceptionally endowed by nature to grapple with it. Another difficulty that Sir Charles Parsons had to contend with was that, in the nature of things, experiments must usually be conducted, in the first instance, on a small scale. Moreover, at that period, when the steam turbine was only employed for driving dynamos, there was no demand for machines of any but what at the present day would be considered of very small size. Now it is one of the peculiarities of steam turbines

that they are much easier to make in large sizes than in small sizes to give reasonable economy. Thus it was by reason of the very small powers that were wanted that in these earlier days turbines earned the opprobrious epithet of "steam-eaters."

The Parsons steam turbine was first chiefly employed for the electric lighting of ships, but in 1887 the whole of the electricity for lighting the Mining, Engineering, and Industrial Exhibition that was held in Newcastle-upon-Tyne was generated by a number of Parsons machines; while a little later the Newcastle and District Electric Lighting Company was formed, the works of which on the banks of the Tyne were the first in which steam turbines were employed to afford a public supply of electricity for general lighting and other purposes. The first machines employed in this station were only of about 100 horsepower, while others of an improved type, which were first employed at Cambridge and at Scarborough, were of about double this power, and were considered as very large. The first steam turbines to be employed in London were used for the lighting of Lincoln's Inn Hall, where they worked for many years, to be followed not long after, in 1891, by three others, each of 50 horse-power, at New Scotland Yard, which still exist, and to-day are providing electricity for lighting, printing, and other purposes, for the Metropolitan Police.

Some fifteen years ago, in evidence that he gave before the Judicial Committee of the Privy Council in connection with Sir Charles Parsons's application for a prolongation of his patent, Lord Kelvin characterised the Parsons turbine as the most important development in steam engines since the days of James Watt. At the time this seemed a somewhat bold assertion, but in the light of experience it has proved to be a fact.

I mentioned just now that it was on the banks of the Tyne that the steam turbine was first applied to the public supply of electricity, and it has also been on the banks of the Tyne, and in the adjacent areas of Northumberland and Durham, that the greatest existing development in this country of electricity supply for industrial purposes has taken place. Not the least of the causes that have led to this is the fact that, apart from London, where the circumstance are very special, in Newcastle-upon-Tyne alone among the great manufacturing cities of Great Britain has electricity supply remained in the hands of private enterprise, and not become municipalised.

The district covered by this vast power-supply undertaking extends as far north as Morpeth, as far west as Consett, is bounded on the east by the sea, and extends right away down through the county of Durham to Stockton-on-Tees, Middlesbrough, and Cleveland. There are seventeen generating stations, of which six are coal-fired stations, and the remainder most interesting waste-heat stations, where steam for making the electricity is obtained either from exhaust steam that has already done work in blowing or other engines, or by steam raised by blast-furnace gas or from the waste heat and gas from coke ovens.

Excepting in the old original power station at Neptune Bank, where power supply was inaugurated by Lord Kelvin in June, 1901, and where there are still some reciprocating engines, the whole of the works are equipped with alternators driven by steam turbines, mostly of the Parsons type, supplying 3-phase 40-cycle current at voltages varying from 3000 to 12,000. The power is supplied to all the leading manufacturers for every kind of purpose, and also to the railway from Newcastle to the sea, which has

been electrified. The total horse-power connected amounts to nearly 200,000.

It is obvious that an undertaking of these vast dimensions, covering as it does large portions of two counties and several large towns and industrial centres, could never have been undertaken by a single municipality. It is equally obvious that it could never have succeeded as well as it has had Newcastle itself, which has been from the first the nucleus of the undertaking, been cut out of the area of supply. This explains why other electric power schemes, such as those being worked on the Clyde and in the area round Glasgow, in Yorkshire and in Lancashire, have failed to go ahead anything like so rapidly as the one of which I have just been speaking. Parliament in its wisdom, at the instance of municipal parochialism, cut nearly all the large towns out of the areas supplied by these schemes, with the result that progress has been impeded with real benefit to no one.

As to the future, we have seen from the lessons of the past how very dangerous it is to prophesy, it being frequently the entirely unexpected that turns up. So far as the immediate future of electricity generation on a large scale is concerned, the steam turbine appears likely to hold the field, though in regard to the smaller stations, where units up to 500 or 1000 kilowatts are what are wanted, the internal-combustion engine is undoubtedly gaining ground. Will it, however, ever catch up the steam turbine in the case of the really large power stations? Turbine units up to 25,000 kilowatts are now in actual use or in contemplation, and as electricity becomes more and more employed, not only for power, but for electrochemical and metallurgical purposes and for domestic heating, we may expect units of plant of still larger dimensions. At present about 2000 horse-power, or about 1500 kilowatts, seems to be about the maximum that it is considered can be safely obtained per cylinder from the internal-combustion engine, so that increased powers can only be obtained by a process of multiplication, which leads, in the case of very large units of plant, to great complication. Then again, as the steam turbine, particularly with the employment of superheated steam, tends to increase in fuel economy as the dimensions of the unit of plant are increased at a much greater ratio than does the internal-combustion engine, a point must be reached when, as we enlarge the units of plant, taking all things, such as first cost, lubricating oil, attendance, and upkeep, into account, the steam turbine will be as cheap as, or even cheaper than, its rival.

So far, the internal-combustion or gas turbine has not been alluded to, but some of the difficulties in the way of its successful realisation may be mentioned. All turbines essentially consist of machines by means of which power is obtained by the passage of fluids or hot gases through narrow apertures, and by their impingement on blades, in such a manner that the fluids or gases are in intimate contact with large surfaces of metal. Now, as all engineers are aware, the law which limits the efficiency obtainable in any heat engine is expressed by the formula  $(T' - T) \div T'$ , where  $T'$  is the absolute temperature of the working gas and  $T$  the absolute temperature of the condenser or the exhaust. From this it is clear that if we are to get maximum efficiencies, the temperature of the working fluid must be as high as possible, and the sole reason for the extra good efficiency of an internal-combustion engine is because in this machine the temperatures that can be successfully dealt with are very high. In the cylinder the combustion takes place when the gas is in considerable mass, and though those portions of it which are in contact with the

walls of the cylinder become cooled, still, the interior of the mass keeps very hot, indeed at temperatures which could not possibly be employed in turbines unless we could find the materials of which to construct the blades which would maintain their tenacity while running at a red heat. It is conceivable that the science of metallurgy may be able to provide new metals or alloys with the necessary properties for doing this in the future, but at present no such material exists, and the only way in which the internal-combustion turbine can for the moment be worked is by reducing the temperatures of the gases by the introduction of water, steam, or air to a reasonable amount; indeed, in practice the temperature has to be reduced to that usual with superheated steam, when, of course, according to the formula I have quoted, the maximum efficiencies theoretically obtainable with the internal-combustion engine and the steam turbine become equal. Even then, if other things were equal, the internal-combustion turbine might have some advantage by doing away with boilers; but, unfortunately, there are other difficulties—such as the bad economy of all methods of compressing the gaseous mixture as is necessary to obtain the full advantage of its combustion.

No doubt the future of electricity supply lies with very large stations employing very big units of plant, and combining the generation of electricity with chemical manufacture, the electricity on the one hand and the chemicals on the other being by-products each of the other's manufacture. So far as this country is concerned, for electricity supply at all events, we are not likely to depart from the use of coal so long as that source of energy holds out. For the propulsion of ships oil may present advantages, but on land in Great Britain coal must remain the cheaper. In all probability, however, in the future the coal will not be simply burnt. It will be turned into gas, and the sulphate of ammonia and the tar, with all its interesting constituents, saved. Whether the gas will be burnt under boilers for the raising of steam to supply steam turbines, or whether it will be used in internal-combustion engines, will depend on the progress made by the latter in regard to attaining larger dimensions, and also as regards improvements in the gas firing of boilers, in respect of which, as has recently been shown by Prof. Bone in his interesting lecture on surface combustion, there is still much to be done.

When the coal and oil and also the peat are exhausted, what then? The date may be distant, but come it must, and that within a period short in comparison with our past civilisation.

The water-power existing on the earth, when all harnessed, would only supply a very small percentage of the demand for power, light, and heat. The utilisation of the tides does not appear a very hopeful project, any more than does the utilisation of the internal heat of the earth. There remain the energy dependent on atomic transformation, the availability of which the highest authorities appear to regard as probably impracticable, and the radiant energy that reaches this planet from the sun. The latter, as calculated by Sir J. J. Thomson, amounts on a clear day to no less than 7000 horse-power per acre, or about 4,500,000 horse-power per square mile of the earth's surface.

Here is obviously an ample supply of energy sufficient for all purposes provided it can be converted into work by some reasonably efficient process. This should not prove impossible, and we have therefore here a problem for the physicist of the utmost importance to the race.